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Ezell

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(54) **HYDROSTATICALLY ACTUABLE DOWNHOLE PISTON**

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E21B 33/128 (2006.01)
E21B 33/1295 (2006.01)
E21B 23/00 (2006.01)

(Continued)

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CPC ***E21B 23/04*** (2013.01); ***E21B 23/06*** (2013.01); *E21B 33/1285* (2013.01); *E21B 33/1295* (2013.01)

(58) **Field of Classification Search**

CPC E21B 23/04; E21B 23/06; E21B 23/00; E21B 23/08

See application file for complete search history.

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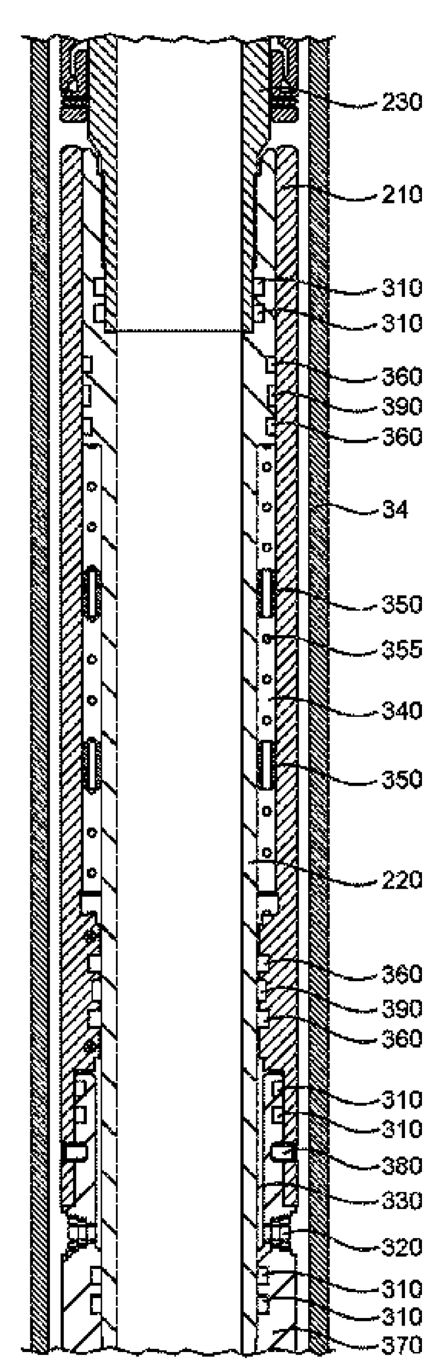
(57) **ABSTRACT**

A hydrostatically actuable downhole piston apparatus for use in a wellbore, comprising glide spacers disposed in the primary chamber, capable of mitigating the deflection of the piston and other hydrostatic components at elevated wellbore hydrostatic pressures. The disclosed apparatus is suited for, among other applications, the hydrostatic setting of a downhole tool, such as a packer, in a wellbore. A method and system for hydrostatically setting a downhole tool using glide spacers disposed in the primary chamber of the downhole tool.

22 Claims, 10 Drawing Sheets



(51) **Int. Cl.**

E21B 23/08	(2006.01)
E21B 19/16	(2006.01)
E21B 34/10	(2006.01)
E21B 34/14	(2006.01)

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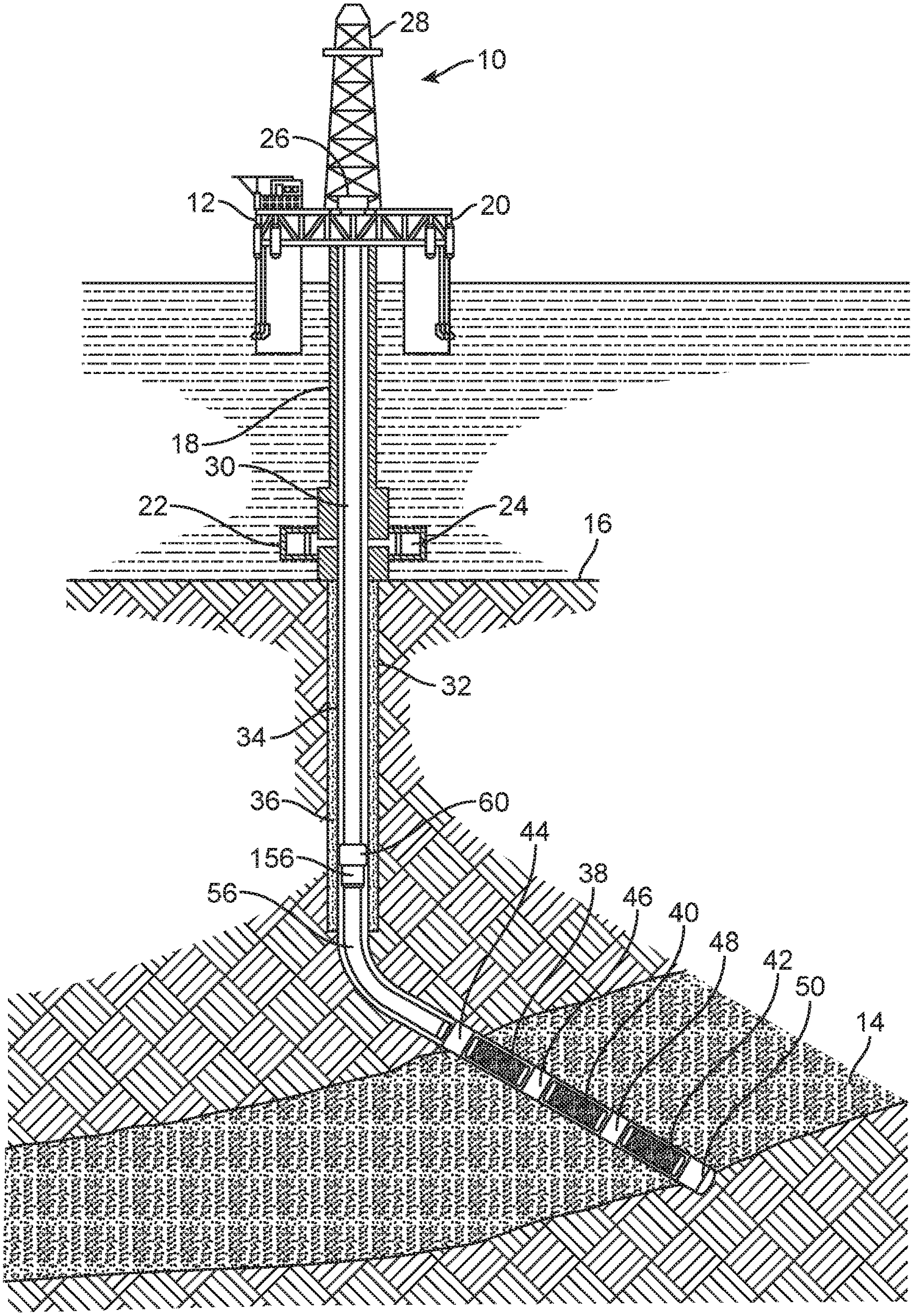


FIG. 1

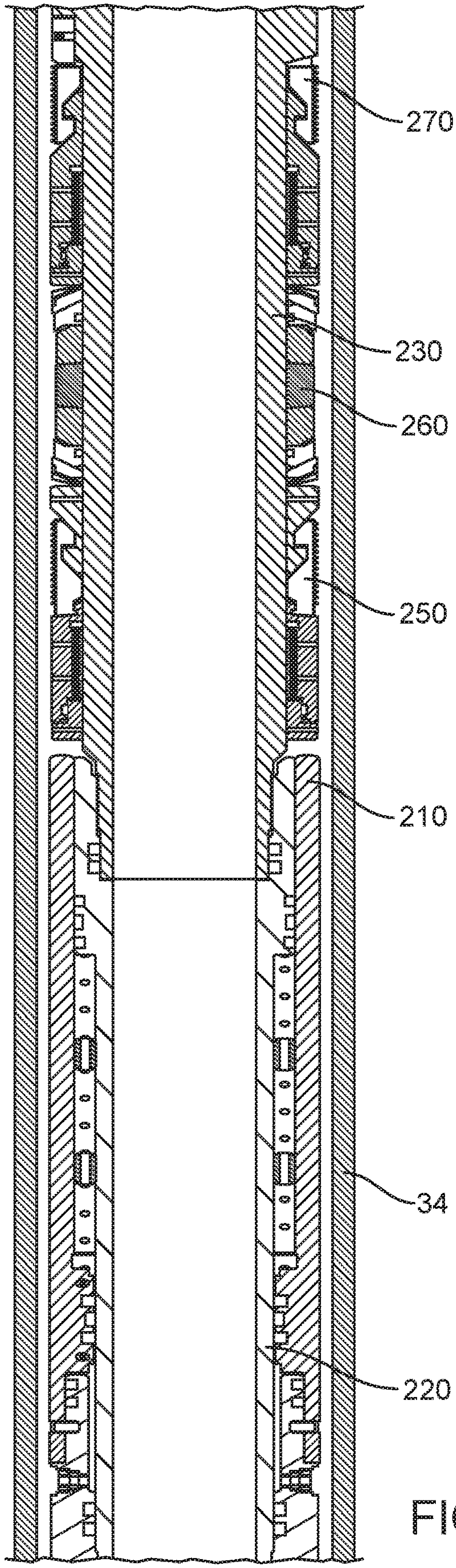
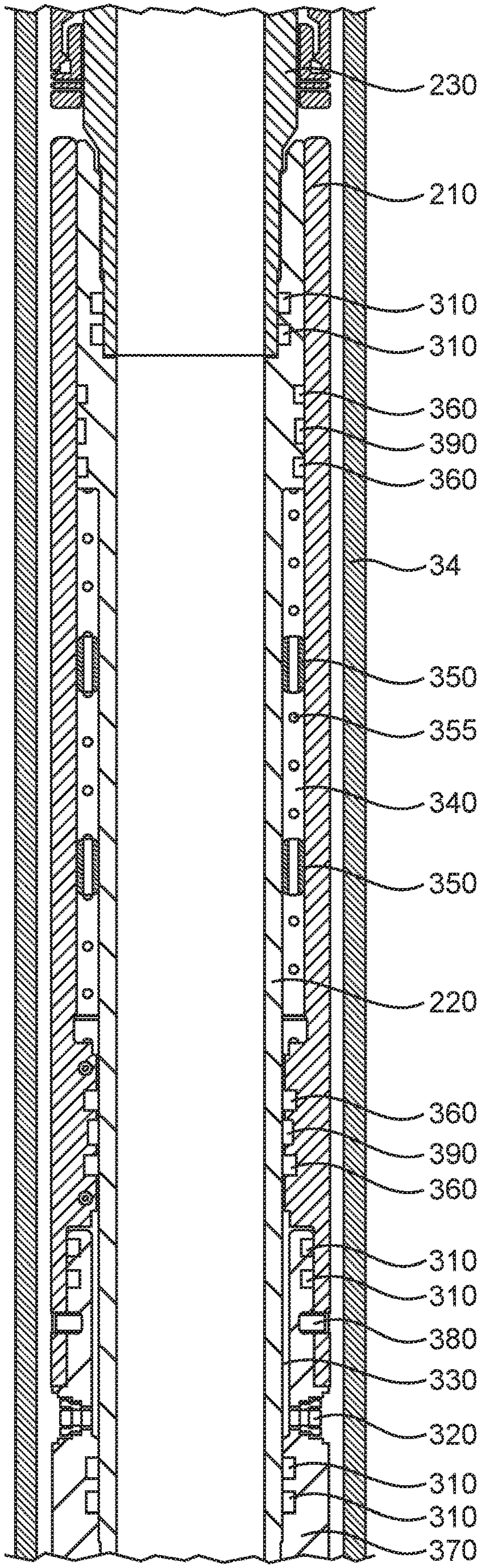


FIG. 2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210
310
310
360
390
360
34
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355
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310
310
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FIG. 3A

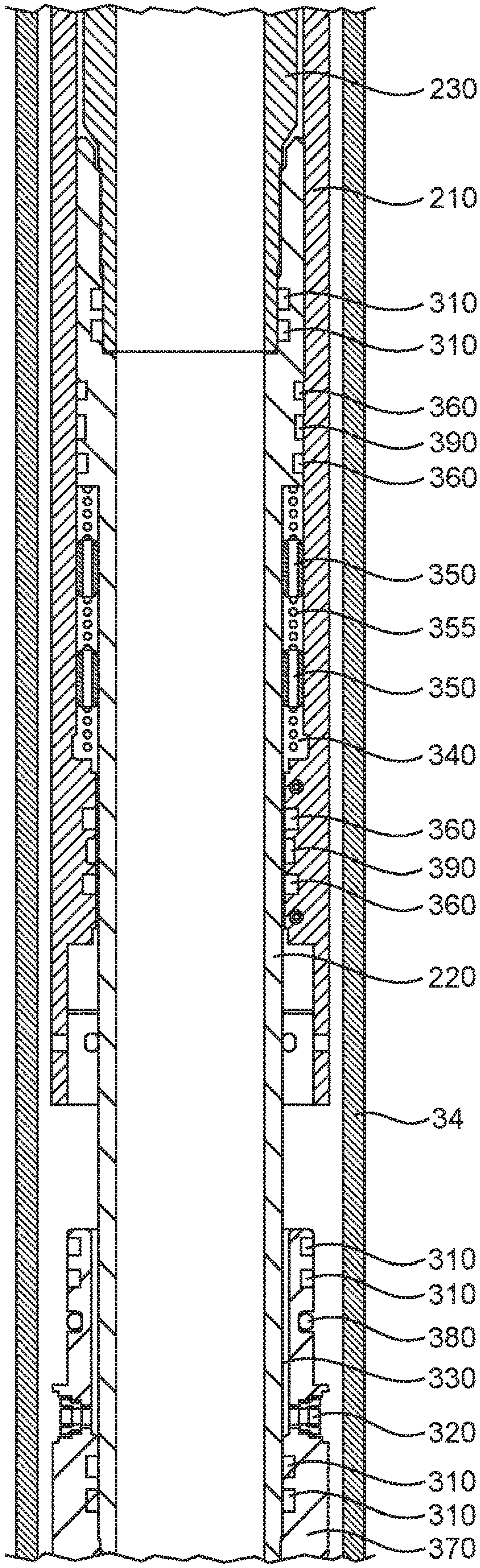
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FIG. 3B

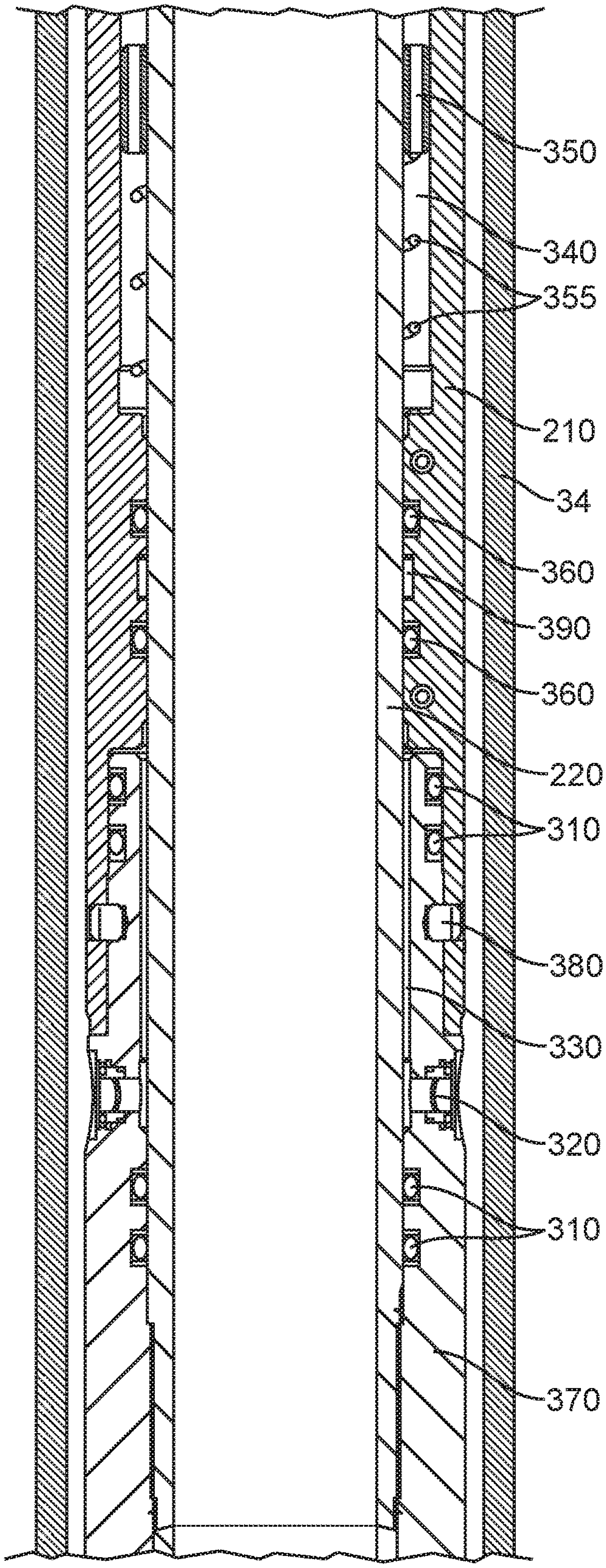

FIG. 4A

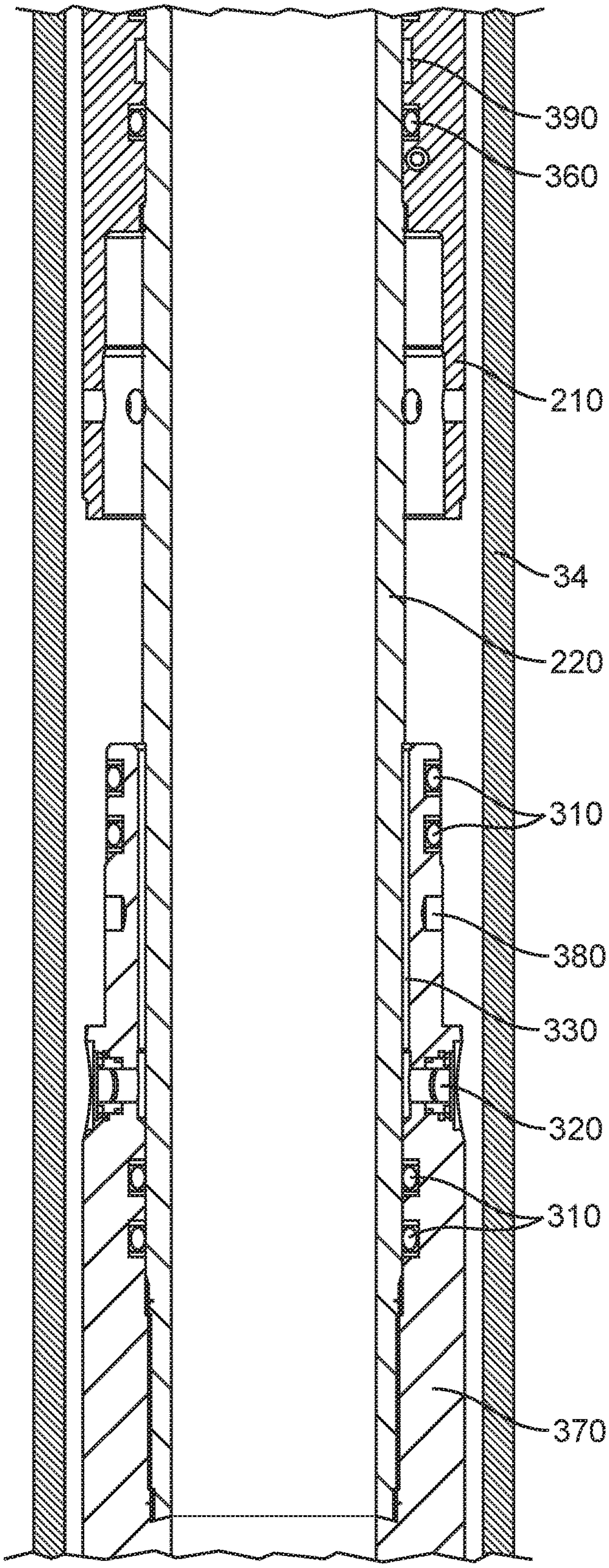

FIG. 4B

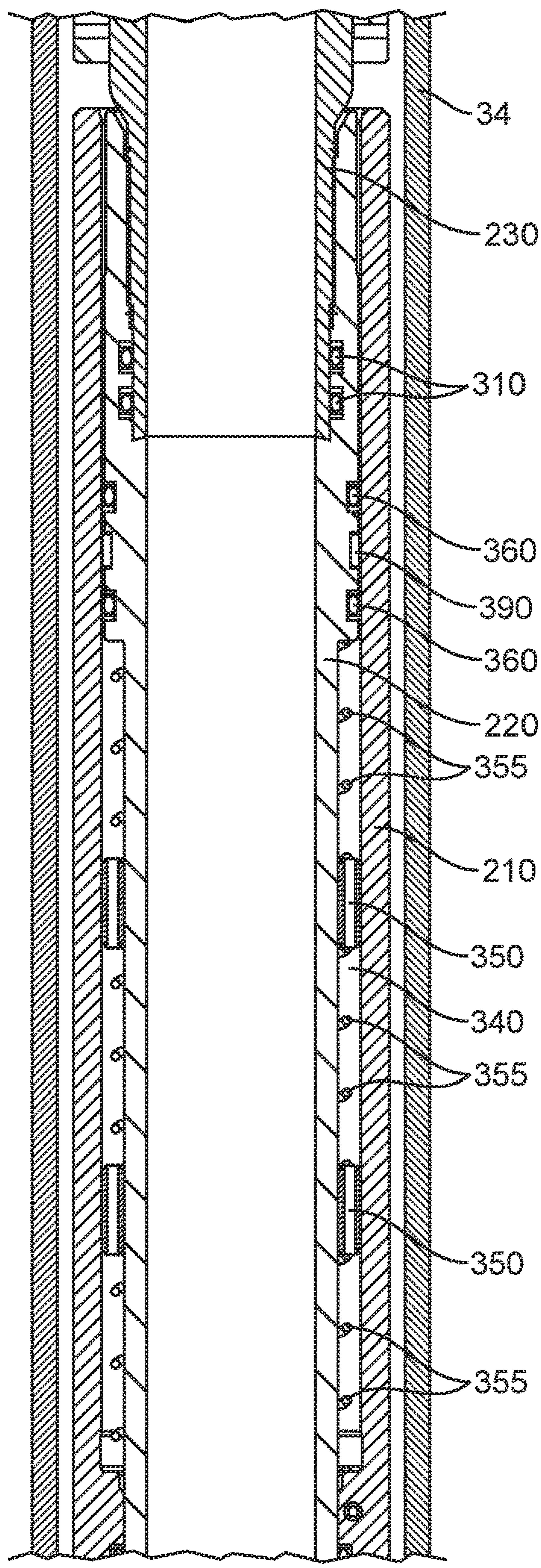

FIG. 5A

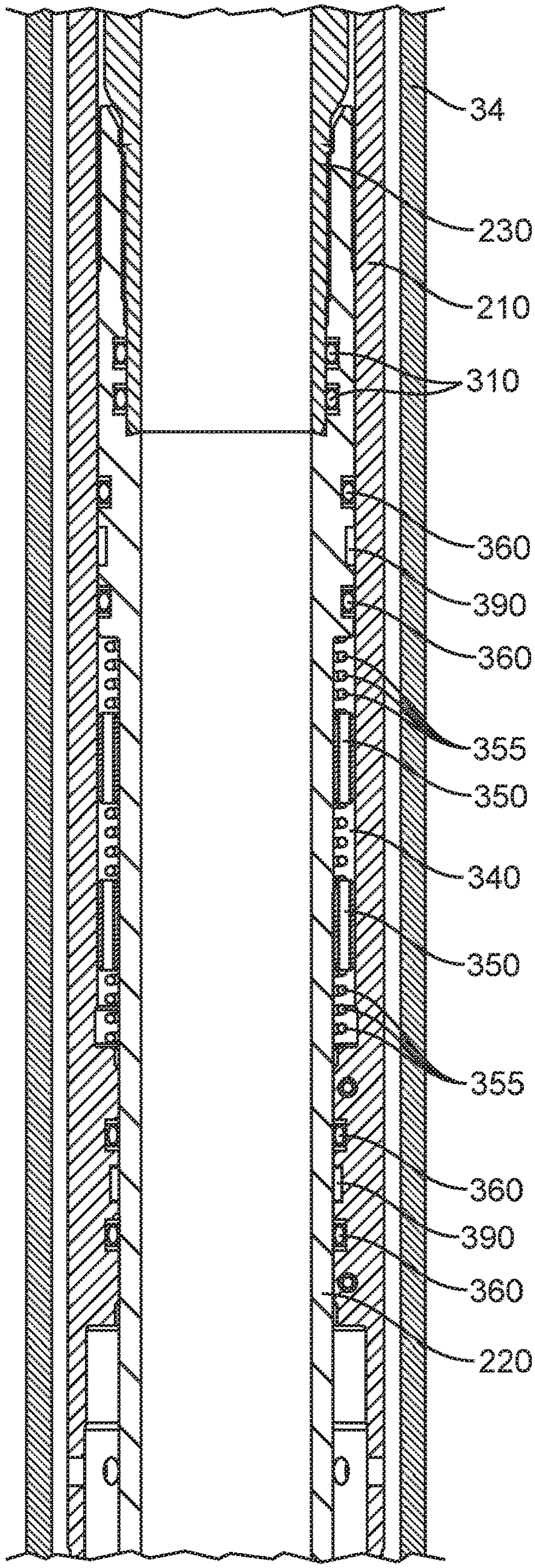

FIG. 5B

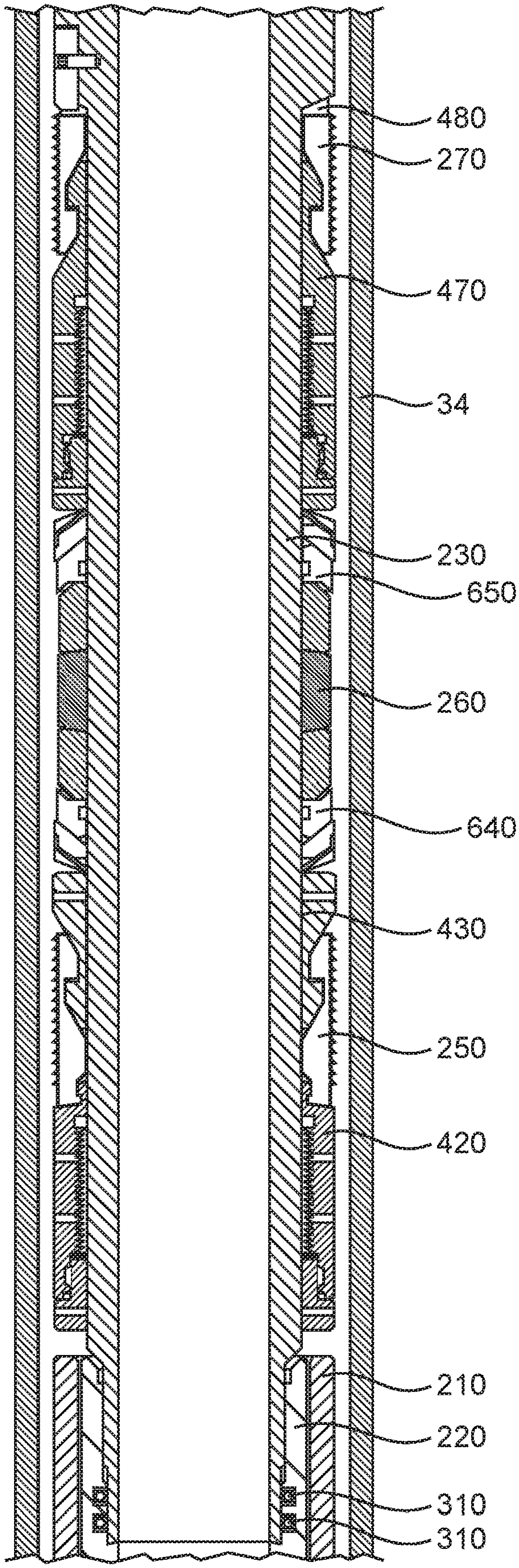

FIG. 6A

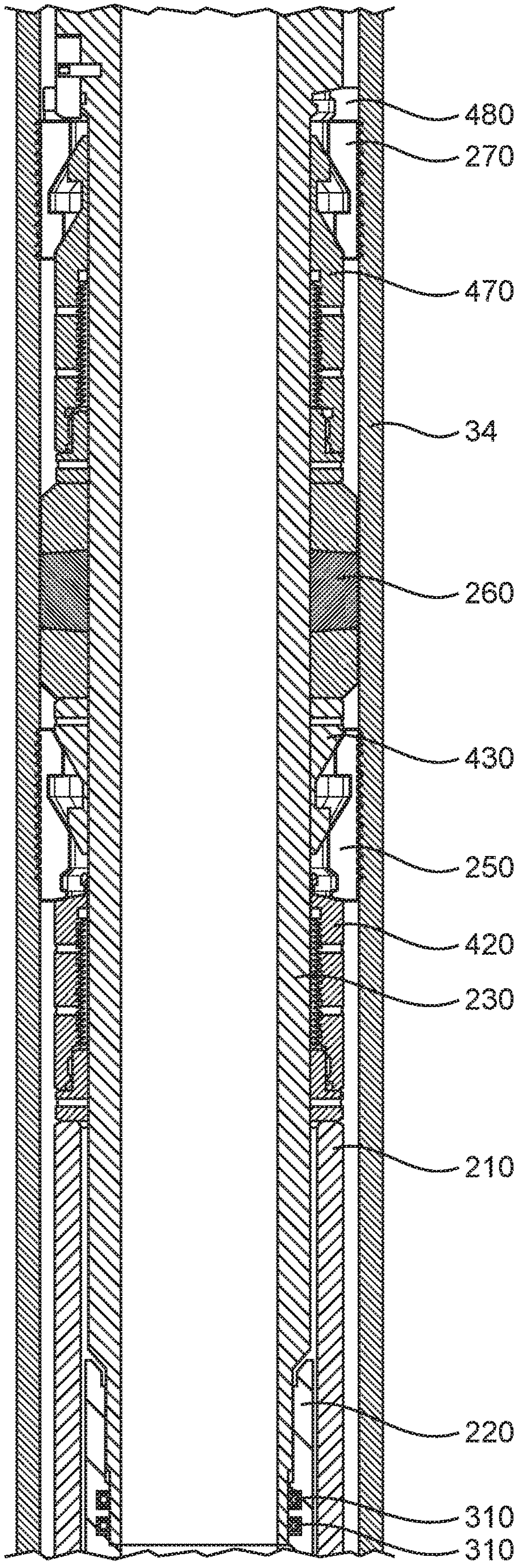

FIG. 6B

HYDROSTATICALLY ACTUABLE DOWNHOLE PISTON

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national stage entry of PCT/US2015/039399 filed Jul. 7, 2015, said application is expressly incorporated herein in its entirety.

FIELD

The present technology relates to hydrostatically actuable pistons used in subterranean wellbores. In particular, the present disclosure relates to hydrostatically actuable pistons operable at elevated hydrostatic pressures.

BACKGROUND

A hydrostatically actuable downhole piston apparatus may be suitably employed in a variety of wellbore tools, including for example packers. Wellbores are drilled into the earth for a variety of purposes including tapping into hydrocarbon bearing formations to extract the hydrocarbons for use as fuel, lubricants, chemical production, and other purposes. When a wellbore has been completed, a metal tubular casing may be placed and cemented in the wellbore. In the process of treating and preparing a subterranean well for production, packers are commonly run into the well on a conveyance such as a work string or production tubing. The purpose of the packer is to support production tubing and other completion equipment by sealing the annulus between the outside of the production tubing and inside of the well casing to block movement of fluids through the annulus past the packer location.

Production packers and other types of downhole tools may be run down on production tubing to a desired depth in the wellbore before they are set. Hydrostatically-actuated downhole tools may be set by a mechanism that involves actuating a piston in response to hydrostatic pressure within production tubing, casing or wellbore. The setting force being generated by applied surface pressure and/or the natural hydrostatic pressure associated with the fluid column in the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to describe the manner in which the advantages and features of the disclosure can be obtained, reference is made to embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only exemplary embodiments of the disclosure and are not therefore to be considered to be limiting of its scope, the principles herein are described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** is a schematic diagram of an embodiment of a wellbore operating environment in which a downhole tool including a hydrostatically actuable downhole piston, such as a packer, may be deployed.

FIG. **2** is a sectional view of an embodiment of a packer including a hydrostatically actuable downhole piston apparatus in the run configuration. FIG. **2** is not drawn to scale, rather, FIG. **2** is exaggerated in the horizontal direction.

FIG. **3**A is a close-up view of FIG. **2** focusing on the chamber portion of the hydrostatically actuable downhole piston apparatus in the run configuration, according an embodiment of this disclosure. FIG. **3**A is not drawn to scale, rather, FIG. **3**A is exaggerated in the horizontal direction.

FIG. **3**B is a close-up view of the same portion of the packer shown in FIG. **3**A, with the hydrostatically actuable downhole piston apparatus in the set configuration, according to an embodiment of this disclosure. FIG. **3**B is not drawn to scale, rather, FIG. **3**B is exaggerated in the horizontal direction.

FIG. **4**A is a close-up view of the portion of the packer shown in FIG. **3**A, focusing on the downhole portion of the hydrostatically actuable downhole piston apparatus in the run configuration, according to an embodiment of this disclosure.

FIG. **4**B is a close-up view of the same portion of the packer shown in FIG. **4**A, with the hydrostatically actuable downhole piston apparatus in the set configuration, according to an embodiment of this disclosure.

FIG. **5**A is a close-up view of the portion of the packer shown in FIG. **3**A, focusing on the glide spacer design of the uphole portion of the hydrostatically actuable downhole piston apparatus in the run configuration, according to an embodiment of this disclosure.

FIG. **5**B is a close-up view of the same portion of the packer shown in FIG. **5**A, with the hydrostatically actuable downhole piston apparatus in the set configuration, according to an embodiment of this disclosure.

FIG. **6**A is a close-up view of FIG. **2** focusing on the slip and seal assemblies of the packer including a hydrostatically actuable downhole piston apparatus in the run configuration, according to an embodiment of this disclosure. FIG. **6**A is not drawn to scale, rather, FIG. **6**A is exaggerated in the horizontal direction.

FIG. **6**B is a close-up view of the same portion of the packer shown in FIG. **6**A, with the hydrostatically actuable downhole piston apparatus in the set configuration, according to an embodiment of this disclosure. FIG. **6**B is not drawn to scale, rather, FIG. **6**B is exaggerated in the horizontal direction.

DETAILED DESCRIPTION

Various embodiments of the disclosure are discussed in detail below. While specific implementations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without parting from the spirit and scope of the disclosure.

It should be understood at the outset that although illustrative implementations of one or more embodiments are illustrated below, the disclosed apparatus, methods, and systems may be implemented using any number of techniques. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques illustrated herein, but may be modified within the scope of the appended claims along with their full scope of equivalents.

Unless otherwise specified, any use of any form of the terms "connect," "engage," "couple," "attach," or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and also may include indirect interaction between the elements described. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . ". Reference to up or down will be made for purposes of description with "up," "upper," "upward," "upstream," or "uphole" meaning toward the surface of the wellbore and with "down," "lower," "downward," "downstream," or "downhole" meaning toward the terminal end of the well, regardless of the wellbore orientation. The various characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description, and by referring to the accompanying drawings.

Description

Disclosed herein is a hydrostatically actuable downhole piston apparatus which may be used in a variety of wellbore tools. One use of a hydrostatically actuable downhole piston apparatus may be as part of a hydrostatic setting system. Downhole tools may be set in the wellbore using a hydrostatic setting system that relies on the differential pressure between the downhole hydrostatic pressure and a pressure within a piston's chamber to actuate a piston which in turn sets the tool. One application of this system is the setting of a packer downhole. The hydrostatically actuable downhole piston apparatus may be suitably employed in shifting sleeves, releasing locking mechanisms as well as other tools.

In particular, the hydrostatic setting system may include a piston that is exposed on one side to an initiation chamber, which is initially closed off to the wellbore annulus fluid by a port isolation device, while the piston is exposed on the other side to a primary chamber. Both the initiation chamber and the primary chamber may be at atmospheric pressure or may be evacuated by pulling a vacuum. Once the downhole tool is positioned at the desired setting depth, pressure may be applied to the production tubing and the wellbore annulus until the port isolation device actuates, thereby allowing wellbore fluid to enter the initiation chamber on one side of the piston while the chamber engaging the other side of the piston remains at atmospheric or evacuated pressure. This creates a differential pressure across the piston that causes the piston to move, initiating the setting process. Once the setting process initiates, O-rings in the initiation chamber may move off seat to open a larger flow area, and the fluid entering the initiation chamber continues actuating the piston to complete the setting process. In the case of a packer, actuation of the piston exerts an upward setting force on the packer thereby driving the packer sealing elements to engage the casing. In other examples, rather than increasing pressure from the surface to actuate the piston, a collet can be used to fix the piston in place, which can then be released, thereby permitting the piston to move due to hydrostatic pressure present in the wellbore.

Typically, as a downhole tool is run downhole, the hydrostatic setting system is exposed to increasing hydrostatic pressure. The increasing hydrostatic pressure may cause deflection of the outer and inner components of the setting system as the differential pressure between the wellbore and the atmospheric chamber of the hydrostatic setting system increases. At higher wellbore pressures deflection of the components around the atmospheric chamber may eventually cause the piston to seize up and inhibit the axial movement of the setting piston.

The present disclosure describes a hydrostatically actuable downhole piston apparatus, method, and system comprising glide spacers disposed in the atmospheric chamber which mitigate the deflection of hydrostatic setting system components and allow free movement of the piston components at elevated hydrostatic pressures.

FIG. **1** illustrates a schematic view of an embodiment of a wellbore operating environment in which a downhole tool including a hydrostatically actuable downhole piston apparatus, such as a packer, may be deployed. As depicted, an offshore oil or gas well **10** may include a semi-submersible platform **12** centered over a submerged oil and gas formation **14** located below the sea floor **16**. A subsea conduit **18** extends from the deck **20** of the platform **12** to a wellhead installation **22**, including blowout preventers **24**. The platform **12** has a hoisting apparatus **26** and a derrick **28** for raising and lowering pipe strings, such as substantially tubular, longitudinally extending inner work string **30**. The wellbore **32** extends through the various earth strata including formation **14**. A casing **34** is cemented within a vertical section of wellbore **32** by cement **36**. An upper end of a liner **56** is secured to the lower end of the casing **34** by any means known in the art, such as expandable liner hangers, and the like.

Note that, in this specification, the terms "liner" and "casing" are used interchangeably to describe tubular materials, which are used to form protective linings in wellbores. It is not necessary for a liner or casing to be cemented in a wellbore. Any type of liner or casing may be used in keeping with the present disclosure.

The liner **56** may include one or more packers **44**, **46**, **48**, **50**, **60** that may be located proximal to the top of the liner **56** or at a lower portion of the liner **56** that provide zonal isolation to the production of hydrocarbons to certain zones of liner **56**. Packers **44**, **46**, **48**, **50**, and **60** may include and be actuated by the hydrostatically actuable downhole piston apparatus, method, and system of the present disclosure. When set, packers **44**, **46**, **48**, **50**, and **60** isolate zones of the annulus between wellbore **32** and casing **34** in between packers **44**, **46**, between packers **46**, **48**, and between packers **48**, **50**. As shown in FIG. **1**, any number of packers may be simultaneously or sequentially run and deployed, such as packers **44**, **46**, **48**, **50**, **60**.

Additionally, liner **56** includes sand control screen assemblies **38**, **40**, and **42** that are located near the lower end of the liner **56** and substantially proximal to the formation **14**. As shown, packers **44**, **46**, **48**, and **50** may be located above and below each set of sand control screen assemblies **38**, **40**, and **42**. Although in the exemplary embodiment, packers are illustrated, the hydrostatically actuable downhole piston apparatus can be employed in other tools and mechanisms as well.

Although FIG. **1** depicts a slanted well, it should be understood by one skilled in the art that the present disclosure describing a hydrostatically actuable downhole piston apparatus, method, and system is equally well-suited for use in vertical wells, horizontal wells, multilateral wells, and the like. Also, although FIG. **1** depicts an offshore operation, it should be understood by one skilled in the art that the present disclosure is equally well-suited for use in onshore operations. Additionally, although FIG. **1** depicts sand control screen assemblies, it should be understood by one skilled in the art that the present disclosure is equally well-suited for use in the absence of sand control screen assemblies.

FIG. **2** illustrates a sectional view of an embodiment of a packer including a hydrostatically actuable downhole piston apparatus in the run position. The hydrostatically actuable downhole piston is set in the run position while the packer is being run into the wellbore and prior to setting the packer at the desired wellbore depth. The packer includes a hydrostatically actuable piston **210** that is slidably disposed about a hydrostatic mandrel **220**. The hydrostatic mandrel **220** is coupled to a packer mandrel **230**. Disposed on the packer mandrel **230** are several packer elements, including the lower slip assembly **250**, upper slip assembly **270**, and seal assembly **260**. In the run position, the hydrostatically actuable piston **210** is spaced apart from the packer mandrel **230** and packer elements, including the lower slip assembly **250**.

FIG. **3**A illustrates a close-up view of FIG. **2** focusing on the chamber portion of the hydrostatically actuable downhole piston apparatus, depicted in the run position. The hydrostatically actuable piston **210** is exposed on one side to an initiation chamber **330** formed between portions of the hydrostatic mandrel **220**, piston **210**, and the bottom sub **370**. The initiation chamber **330** is initially closed off to the wellbore annulus fluid by a rupture disc **320** (port isolation device) that is housed in the bottom sub **370**. The initiation chamber **330** may be at atmospheric pressure (at the surface) or may be evacuated by pulling a vacuum. The burst pressure of the rupture disc **320** may be set higher than the anticipated hydrostatic pressure at the setting depth.

The other side of the hydrostatic piston **210** is exposed to a primary chamber **340** that may be at atmospheric pressure or may be evacuated by pulling a vacuum. According to the present disclosure, glide spacers **350** are disposed within the primary chamber **340** so as to mitigate deflection of the hydrostatically actuable piston **210** and the hydrostatic mandrel **220**.

Initially, relative movement between the hydrostatically actuable piston **210** and the hydrostatic mandrel **220** is opposed by a shear screw **380** that couples a portion of the piston **210** to the bottom sub **370**. The shear screw **380** operates as a safety mechanism preventing the packer from setting upon premature rupture of the rupture disc **320**.

When the packer is lowered to the desired wellbore depth, the pressure in the annulus is raised or reaches a predetermined level and the rupture disc **320** ruptures allowing pressure communication between the annulus and the initiation chamber **330** to start driving the piston **210**. The initial movement of the piston **210** shears the shear screw **380** allowing the pressure difference between the initiation chamber **330** and the primary chamber **340** to shift the piston **210** longitudinally relative to the hydrostatic mandrel **220** and toward the packer mandrel **230**.

FIG. **3**B illustrates a close-up view of the same portion of the packer shown in FIG. **3**A, but with the hydrostatically actuable downhole piston apparatus depicted in the set position. As shown in FIG. **3**B, the hydrostatically actuable piston **210** has shifted longitudinally toward the packer mandrel **230** (as well as the seal and slip assemblies) and away from the bottom sub **370** in response to the pressure difference between the initiation chamber **330** and the primary chamber **340**.

FIG. **4**A illustrates a close-up view of the lower portion of FIG. **3**A, focusing on the downhole portion of the hydrostatically actuable piston **210** in the run position. The initiation chamber **330** is formed between portions of the hydrostatic mandrel **220**, piston **210**, and the bottom sub **370**. Seals **310** are located between bottom sub **370** and piston **210**, as well as between the hydrostatic mandrel **220** and the bottom sub **370**, to provide a sealing relationship between the hydrostatic mandrel **220**, piston **210**, and the bottom sub **370**.

A third set of seals **360**, operable to seal the hydrostatic mandrel **220** and piston **210**, are located longitudinally between the initiation chamber **330** and the primary chamber **340**. In between these seals **360**, a centralizer ring **390** serves to properly position the piston **210** about the hydrostatic mandrel **220** and to help form a uniformly shaped chamber.

Seals **310**, **360** may consist of any suitable sealing element or elements, such as a single O-ring, a plurality of O-rings, and/or a combination of backup rings, O-rings, and the like. Seals **310**, **360** and/or centralizer rings **390** may comprise AFLAS® O-rings with PEEK back-ups for severe downhole environments, Viton O-rings for low temperature service, nitrile or hydrogenated nitrile O-rings for high pressure and temperature service, or a combination thereof.

The initiation chamber **330** is separated from the wellbore annulus by the rupture disc **320** (port isolation device) housed in the bottom sub **370**. Initial movement of the piston **210** is opposed by the shear screw **380** which couples a portion of the piston **210** to the bottom sub **370**.

It should be recognized by those skilled in the art that other port isolation devices may be used to communicate pressure in the annulus to the piston, such devices being considered within the scope of the present disclosure. Additionally, it should be recognized by those skilled in the art that other mechanisms for hydrostatically actuating the hydrostatically actuable piston may utilized, including the use of release assemblies that are actuated by the profile of the wellbore, including but not limited to the use of a collet assembly. Further, it should be recognized by those skilled in the art that a shear screw is optional and that the present disclosure is equally well-suited for use in the absence of a shear screw.

FIG. **4**B illustrates a close-up view of the same portion of the packer shown in FIG. **4**A, but with the hydrostatically actuable downhole piston apparatus depicted in the set position. As shown in FIG. **4**B, the shear screw **380** has been sheared and the hydrostatically actuable piston **210** has shifted longitudinally uphole.

FIG. **5**A illustrates a close-up view of FIG. **3**A, focusing on the design of the glide spacers **350** positioned in the primary chamber **340**, with the hydrostatically actuable piston **210** in the run position. The glide spacers **350** are spaced so as to provide for much shorter unsupported intervals of the piston **210** and hydrostatic mandrel **220** while providing for low friction movement of the hydrostatic piston **210** relative to the hydrostatic mandrel **220** when the glide spacers **350** are in full contact with the deflecting piston **210** and hydrostatic mandrel **220**.

The glide spacers **350** in the illustrated embodiment are annular, substantially surrounding the hydrostatic mandrel **220**. In other instances, rather than encircling the hydrostatic mandrel **220**, the glide spacers **350** can extend a portion of the distance. In other examples, a the glide spacers **350** can be provided as a plurality of smaller individual arcuate pucks spaced about the hydrostatic mandrel **220**.

Optionally, the glide spacers **350** may include a passageway providing pressure communication between different portions of the primary chamber **340** otherwise separated by the glide spacers **350**. The glide spacers **350** may also optionally be maintained in position prior to longitudinal movement of the piston **210** by one or more springs **355** or other retainer system. Optionally, the retainer system may be capable of contracting or otherwise allowing the glide spacers **350** to move within the primary chamber **340** so as to not impede the setting stroke of the hydrostatically actuable piston **210**.

The glide spacers **350** have a thickness sufficient to resist deflection of the hydrostatic piston **210** toward the hydrostatic mandrel **220** for at least a portion of the radial thickness of the primary chamber **340**. In some cases, the glide spacer **350** may have a radial thickness essentially equal to the radial thickness of the primary chamber **340**.

While two glide spacers **350** are shown in FIG. **5**A, it should be understood by one skilled in the art that fewer or more numerous glide spacers **350** may be used according to this disclosure, so long as the glide spacers **350** provide sufficient support such that deflection of the piston **210** and hydrostatic mandrel **220** is mitigated under wellbore hydrostatic pressures. For instance, in some cases, a single glide spacer **350** in the primary chamber **340** may be sufficient. Alternatively, a plurality of glide spacers **350** in the primary chamber **340** may be necessary to support the piston **210** and hydrostatic mandrel **220**, for example 2-6 glide spacers, depending on the degree of expected hydrostatic pressures or length of the primary chamber **340**.

The glide spacers **350** may be made of any material that provides for low friction movement of the hydrostatically actuable piston **210** relative to the hydrostatic mandrel **220** when the glide spacers **350** are in full contact with the deflecting piston **210** and hydrostatic mandrel **220** and that is further capable of spacing apart the hydrostatic piston **210** and hydrostatic mandrel **220** under hydrostatic pressures characteristic of the wellbore. Suitable materials may include, but are not limited to, PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), nickel-filled PTFE (TFN), or any combination thereof. Various hydrocarbon based lubricants may be provided in the primary chamber **340** or on the glide spacers **350** to facilitate sliding of the glide spacers **350**.

FIG. **5**B illustrates a close-up view of the same portion of the packer shown in FIG. **5**A, with the hydrostatically actuable piston apparatus depicted in the set configuration. As shown in FIG. **5**B, the piston **210** and the glide spacers **350** have shifted longitudinally in the uphole direction, toward the packer mandrel **230**. The longitudinal movement of the glide spacers **350** provides for low friction movement of the hydrostatic piston **210** relative to the hydrostatic mandrel **220** when the glide spacers **350** are in full contact with the deflecting piston **210** and hydrostatic mandrel **220**.

FIG. **6**A illustrates a close-up view of FIG. **2** focusing on the slip assembly **250**, **270** and seal assembly **260** portion of the hydrostatically actuable downhole piston apparatus, depicted in the run position. As shown in FIG. **6**A, when the apparatus is in the run configuration, the hydrostatically actuable piston **210** is spaced apart from the lower first wedge **420** disposed about the packer mandrel **230**. The lower slip assembly **250** is located between the lower first wedge **420** and the lower second wedge **430**. The lower first wedge **420** has a camming outer surface that is capable of engaging an inner surface of the lower slip assembly **250**. The lower slip assembly **250** may have teeth located along its outer surface for providing a gripping arrangement with the interior of the well casing **34**. As explained in greater detail below, when a compressive force is generated between the lower first wedge **420**, lower slip assembly **250**, and lower second wedge **430**, by actuation of the hydrostatic piston **210**, the lower slip assembly **250** radially extends into contact with the well casing **34**, thereby setting the packer. It should be apparent to those skilled in the art that the slip assembly **250** and the lower first wedge **420** and the lower second wedge **430** may have a variety of different configurations including but not limited to having differently shaped wedge sections, different numbers of wedge sections, and/or slip assemblies of different designs, such configurations being considered within the scope of the present disclosure.

Substantially adjacent to the lower second wedge **430** is a lower element backup shoe **640** that is slidably positioned around the packer mandrel **230**. Additionally, a seal assembly **260**, depicted as three expandable seal elements, is slidably positioned around packer mandrel **230** between the lower element backup shoe **640** and the upper element backup shoe **650**. In the illustrated embodiment, three expandable seal elements are shown, however, a seal assembly **260** according to the present disclosure may include any number of expandable seal elements.

The lower element backup shoe **640** and the upper element backup shoe **650** may be made from a deformable or malleable material, such as mild steel, soft steel, brass, and the like and may be thin cut at their distal ends. The ends of lower element backup shoe **640** and upper element backup shoe **650** may deform and flare outwardly toward the inner surface of the casing or formation during the setting sequence. In some cases, the lower element backup shoe **640** and the upper element backup shoe **650** form a metal-to-metal barrier between the packer and the inner surface of the casing.

Substantially adjacent to the upper element backup shoe **650** is a upper first wedge **470** that is disposed about the packer mandrel **230**. The upper first wedge **470** has a camming outer surface that will engage an inner surface of the upper slip assembly **270**. The upper slip assembly **270** is located between the upper first wedge **470** and the upper second wedge **480**. In some cases, the upper slip assembly **270** may have teeth located along its outer surface for providing a gripping arrangement with the interior of the well casing. As explained in greater detail below, when a compressive force is generated between the upper first wedge **470**, upper slip assembly **270**, and upper second wedge **480**, the upper slip assembly **270** is radially extended into contact with the well casing. As should be apparent to those skilled in the art, the upper slip assembly **270**, the upper first wedge **470** and the upper second wedge **480** may have a variety of configurations including but not limited to having differently shaped wedge sections, different numbers of wedge sections, and/or slip assemblies of different designs, such configurations being considered within the scope of the present disclosure.

Upon actuation of the hydrostatically actuable piston **210**, the hydrostatically actuable piston **210** shifts longitudinally to exert an upward force on the lower first wedge **420** causing the lower first wedge **420** to move upward towards the lower slip assembly **250**. As the lower first wedge **420** contacts the lower slip assembly **250**, the lower slip assembly **250** moves upwardly over the lower second wedge **430**, which starts to set the lower slip assembly **250** against the inner surface of a setting surface, such as the casing **34**.

As the lower slip assembly **250** extends outwardly toward the inner surface of the casing **34**, it further moves upward causing an upward force on the lower second wedge **430** which in turn moves upward forcing the lower element backup shoe **640** to begin to move upward relative to the packer mandrel **230**. As the piston **210**, lower first wedge **420**, lower slip assembly **250**, lower second wedge **430**, and lower element backup shoe **640** begin to move upward, the seal assembly **260**, consisting of three expandable seal elements, begins to move upward and also begins to extend outwardly toward the casing **34**.

In some cases, the upward movement of the seal assembly **260**, consisting of expandable seal elements, forces the lower element backup shoe **640** and the upper element backup shoe **650** to flare outward toward the casing **34** to provide a metal-to-metal seal (not shown in FIG. **6**A) in addition to the seal of the expandable seal elements between the casing **34** and the packer mandrel **230**.

Upon the upward and sealingly movement of the lower element backup shoe **640**, seal assembly **260**, consisting of expandable seal elements, and upper element backup shoe **650**, an upward force is transmitted to the upper first wedge **470** causing the upper first wedge **470** to contact the upper slip assembly **270**. Once the upper first wedge **470** acts upon the upper slip assembly **270**, the upper slip assembly **270** moves upwardly over the upper second wedge **480**, which moves the upper slip assembly **270** outwardly against the inner surface of the casing **34**, setting the packer.

FIG. **6**B is a close-up view of the same portion of the packer shown in FIG. **6**A, with the hydrostatically actuable downhole piston **210** apparatus in the set configuration. As depicted in FIG. **6**B, the hydrostatic piston has shifted longitudinally toward the lower slip assembly **250**, the seal assembly **260**, and the upper slip assembly **270**, thereby actuating the slip assemblies **250**, **270** and seal assembly **260** to a radially expanded sealing position and setting the packer.

Numerous examples are provided herein to enhance understanding of the present disclosure. A specific set of examples are provided as follows.

In a first example, there is disclosed a hydrostatically actuable downhole piston apparatus including at least one mandrel having an internal bore, a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber containing a glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber, wherein the hydrostatic piston has a first fixed configuration which responsive to an increase in pressure external to the chamber shifts longitudinally relative to the mandrel.

In a second example, an apparatus is disclosed according to the preceding example further including a slip assembly disposed on the mandrel having a radially extendible surface, wherein the surface extends responsive to the longitudinal shift of the hydrostatic piston.

In a third example, an apparatus is disclosed according to any of the preceding examples, further including a seal assembly disposed on the mandrel having a radially extendible seal, wherein the seal extends responsive to the longitudinal shift of the hydrostatic piston.

In a fourth example, an apparatus is disclosed according to any of the preceding examples, wherein the chamber is at a pressure equal to or below surface atmospheric pressure.

In a fifth example, an apparatus is disclosed according to any of the preceding examples, wherein the glide spacer has a radial thickness essentially equal to the radial thickness of the chamber.

In a sixth example, an apparatus is disclosed according to any of the preceding examples, wherein the glide spacer comprises a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

In a seventh example, an apparatus is disclosed according to any of the preceding examples, further including a plurality of glide spacers.

In an eighth example, an apparatus is disclosed according to any of the preceding examples, wherein the glide spacer is maintained in position prior to the longitudinal shifting of the piston by a retainer.

In a ninth example, an apparatus is disclosed according to any of the preceding examples, wherein the retainer comprises a spring.

In a tenth example, an apparatus is disclosed according to any of the preceding examples, wherein the glide spacer comprises at least one material selected from the group consisting of PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), and nickel-filled PTFE (TFN).

In an eleventh example, a method of hydrostatically setting a downhole tool in a wellbore is disclosed, including running a downhole tool into the wellbore to a setting depth, wherein the downhole tool includes at least one mandrel having an internal bore, a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber containing at least one glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber, wherein the hydrostatic piston has a first fixed configuration, and a slip assembly disposed on the mandrel having a radially extendible surface, and wherein responsive to an increase in hydrostatic pressure in the wellbore external to the chamber, the hydrostatic piston shifts longitudinally from its fixed configuration actuating the slip assembly to extend the extendible surface, thereby setting the downhole tool within the wellbore.

In a twelfth example, a method is disclosed according to any of the preceding examples, wherein the downhole tool is a packer.

In a thirteenth example, a method is disclosed according to any of the preceding examples, wherein the downhole tool further includes a seal assembly disposed on the mandrel having a radially extendible seal, wherein the seal extends responsive to the longitudinal shift of the hydrostatic piston.

In a fourteenth example, a method is disclosed according to any of the preceding examples, wherein the chamber is at a pressure equal to or below surface atmospheric pressure.

In a fifteenth example, a method is disclosed according to any of the preceding examples, wherein the at least one glide spacer has a radial thickness essentially equal to the radial thickness of the chamber.

In a sixteenth example, a method is disclosed according to any of the preceding examples, wherein the at least one glide spacer includes a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

In a seventeenth example, a method is disclosed according to any of the preceding examples, wherein the downhole tool further includes a plurality of glide spacers.

In an eighteenth example, a method is disclosed according to any of the preceding examples, wherein the at least one glide spacer is maintained in position prior to the longitudinal shifting of the piston by a retainer.

In a nineteenth example, a method is disclosed according to any of the preceding examples, wherein the retainer comprises a spring.

In a twentieth example, a method is disclosed according to any of the preceding examples, wherein the at least one glide spacer comprises at least one material selected from the group consisting of PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), and nickel-filled PTFE (TFN).

In a twenty-first example, a hydrostatic pressure setting system is disclosed, including a downhole tool provided within a wellbore, the downhole tool including at least one mandrel having an internal bore, a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber containing at least one glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber, wherein the hydrostatic piston has a first fixed configuration which responsive to an increase in pressure external to the chamber shifts longitudinally relative to the mandrel, a slip assembly disposed on the mandrel having a surface which radially extends in response to the longitudinal shift of the hydrostatic piston thereby setting the downhole tool within the wellbore.

In a twenty-second example, a system is disclosed according to any of the preceding examples, wherein the downhole tool is a packer.

In a twenty-third example, a system is disclosed according to any of the preceding examples, wherein the at least one glide spacer comprises a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

In a twenty-fourth example, a system is disclosed according to any of the preceding examples, wherein the downhole tool further includes a seal assembly disposed on the mandrel having a radially extendible seal, wherein the seal extends responsive to the longitudinal shift of the hydrostatic piston.

In a twenty-fifth example, a system is disclosed according to any of the preceding examples, wherein the chamber is at a pressure equal to or below surface atmospheric pressure.

In a twenty-sixth example, a system is disclosed according to any of the preceding examples, wherein the at least one glide spacer has a radial thickness essentially equal to the radial thickness of the chamber.

In a twenty-seventh example, a system is disclosed according to any of the preceding examples, wherein the downhole tool further includes a plurality of glide spacers.

In a twenty-eighth example, a system is disclosed according to any of the preceding examples, wherein the at least one glide spacer is maintained in position prior to the longitudinal shifting of the piston by a retainer.

In a twenty-ninth example, a system is disclosed according to any of the preceding examples, wherein the retainer comprises a spring.

In a thirtieth example, a system is disclosed according to any of the preceding examples, wherein the at least one glide spacer comprises at least one material selected from the group consisting of PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), and nickel-filled PTFE (TFN).

Although a variety of examples and other information was used to explain aspects within the scope of the appended claims, no limitation of the claims should be implied based on particular features or arrangements in such examples, as one of ordinary skill would be able to use these examples to derive a wide variety of implementations. Further and although some subject matter may have been described in language specific to examples of structural features and/or method steps, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to these described features or acts. For example, such functionality can be distributed differently or performed in components other than those identified herein. Rather, the described features and steps are disclosed as examples of components of systems and methods within the scope of the appended claims. Moreover, claim language reciting "at least one of" a set indicates that a system including either one member of the set, or multiple members of the set, or all members of the set, satisfies the claim.

I claim:

1. A hydrostatically actuable downhole piston apparatus comprising:

a mandrel having an internal bore;

a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber having a predetermined length; and

at least one glide spacer disposed within the chamber and positioned substantially equidistant along the predetermined length so as to provide for a shorter unsupported portion or portions of the chamber along the predetermined length, the at least one glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber,

wherein the hydrostatic piston has a first fixed configuration which responsive to an increase in pressure external to the chamber shifts longitudinally relative to the mandrel, and

wherein the at least one glide spacer is operable to move longitudinally within the chamber when the piston shifts longitudinally.

2. The hydrostatically actuable downhole piston apparatus according to claim **1**, further comprising a slip assembly disposed on the mandrel having a radially extendible surface, wherein the surface extends responsive to the longitudinal shift of the hydrostatic piston.

3. The hydrostatically actuable downhole piston apparatus according to claim **2**, further comprising a seal assembly disposed on the mandrel having a radially extendible seal, wherein the seal extends responsive to the longitudinal shift of the hydrostatic piston.

4. The hydrostatically actuable downhole piston apparatus according to claim **1**, wherein the chamber is at a pressure equal to or below surface atmospheric pressure.

5. The hydrostatically actuable downhole piston apparatus according to claim **1**, wherein the at least one glide spacer has a radial thickness essentially equal to the radial thickness of the chamber.

6. The hydrostatically actuable downhole piston apparatus according to claim **1**, wherein the at least one glide spacer comprises a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

7. The hydrostatically actuable downhole piston apparatus according to claim **1**, further comprising a plurality of glide spacers, the plurality of glide spacers spaced about the mandrel substantially equidistant along the predetermined length.

8. The hydrostatically actuable downhole piston apparatus according to claim **1**, wherein the glide spacer is maintained in position prior to the longitudinal shifting of the piston by a retainer, the retainer further operable to contract or otherwise allow the at least one glide spacer to move within the chamber so as to not impede longitudinal shifting of the piston.

9. The hydrostatically actuable downhole piston apparatus according to claim **8**, wherein the retainer comprises a spring.

10. The hydrostatically actuable downhole piston apparatus according to claim **8**, wherein the glide spacer comprises at least one material selected from the group consisting of PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), and nickel-filled PTFE (TFN).

11. The hydrostatically actuable downhole piston apparatus according to claim **1**, wherein the glide spacer is in contact with the hydrostatic piston and the mandrel.

12. The hydrostatically actuable downhole piston apparatus according to claim **1**, further comprising an upper glide spacer and a lower glide spacer spaced apart along the chamber and positioned substantially equidistant along the predetermined length of the chamber.

13. A method of hydrostatically setting a downhole tool in a wellbore, comprising:

running the downhole tool into the wellbore to a setting depth, wherein the downhole tool comprises:

at least one mandrel having an internal bore;

a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber having a predetermined length and containing at least one glide spacer disposed within the chamber and positioned substantially equidistant along the predetermined length so as to provide for a shorter unsupported portion or portions of the chamber along the predetermined length, the at least one glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber, wherein the hydrostatic piston has a first fixed configuration; and

a slip assembly disposed on the mandrel having a radially extendible surface, and

wherein

responsive to an increase in hydrostatic pressure in the wellbore external to the chamber, the hydrostatic piston shifts longitudinally from its fixed configuration actuating the slip assembly to extend the extendible surface, thereby setting the downhole tool within the wellbore,

wherein the at least one glide spacer is operable to move longitudinally within the chamber when the piston shifts longitudinally.

14. The method according to claim **13**, wherein the downhole tool is a packer.

15. The method according to claim **13**, wherein the at least one glide spacer comprises a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

16. The method according to claim **13**, wherein the at least one glide spacer is maintained in position prior to the longitudinal shifting of the piston by a retainer.

17. The method according to claim **16**, wherein the retainer comprises a spring.

18. The method according to claim **13**, wherein the at least one glide spacer comprises at least one material selected from the group consisting of PEEK, glass-filled PTFE (TFG), bronze-filled PTFE (TFB), and nickel-filled PTFE (TFN).

19. The method according to claim **13**, further comprising evacuating the chamber by pulling a vacuum when the hydrostatic piston is in the first fixed configuration.

20. A hydrostatic pressure setting system comprising:

a downhole tool provided within a wellbore, the downhole tool comprising:

at least one mandrel having an internal bore;

a hydrostatic piston slidably disposed about the mandrel and forming a sealed chamber between the mandrel and the hydrostatic piston, the chamber having a predetermined length and containing at least one glide spacer disposed within the chamber and positioned substantially equidistant along the predetermined length so as to provide for a shorter unsupported portion or portions of the chamber along the predetermined length, the at least one glide spacer having a thickness sufficient to resist deflection of the hydrostatic piston toward the mandrel for at least a portion of the radial thickness of the chamber, wherein the hydrostatic piston has a first fixed configuration which responsive to an increase in pressure external to the chamber shifts longitudinally relative to the mandrel; and

a slip assembly disposed on the mandrel having a surface which radially extends in response to the longitudinal shift of the hydrostatic piston thereby setting the downhole tool within the wellbore,

wherein the at least one glide spacer is operable to move longitudinally within the chamber when the piston shifts longitudinally.

21. The system according to claim **20**, wherein the downhole tool is a packer.

22. The system according to claim **20**, wherein the at least one glide spacer comprises a passageway providing pressure communication between different portions of the chamber otherwise separated by the glide spacer.

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